Image-Guided Brachytherapy

Pooriwat M, MD
DOSE EFFECT RELATIONSHIP POINT A

<table>
<thead>
<tr>
<th>Stage</th>
<th>Dose pt A</th>
<th>Pelvic failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage IB and IIA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(&lt;2 cm)</td>
<td>70-80 Gy</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>(&gt;2 cm)</td>
<td>up to 85-90 Gy</td>
<td></td>
</tr>
<tr>
<td>Stage IIB</td>
<td>70 Gy</td>
<td>50%</td>
</tr>
<tr>
<td>nonbulky</td>
<td>&gt;80 Gy</td>
<td>20%</td>
</tr>
<tr>
<td>bulky</td>
<td>&gt;80 Gy</td>
<td>30%</td>
</tr>
<tr>
<td>Stage III unilateral</td>
<td>up to 70 Gy</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>&gt;70 Gy</td>
<td>35%</td>
</tr>
<tr>
<td>Stage III bilateral/bulky</td>
<td>&lt; 70 Gy</td>
<td>60%</td>
</tr>
<tr>
<td></td>
<td>&gt;70 Gy</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>&gt;85 Gy</td>
<td>35%</td>
</tr>
</tbody>
</table>

\[N=1499\]

Refinements in brachytherapy techniques are necessary to improve the present results (Perez et al IJROBP 1998)
• Web-based database with a retrospective multicentre collection of data on 3D RT plus IGABT in cervical cancer

• 780 pts

• Eligibility criteria:
  • Diagnosis of cervical cancer and treatment with curative intent by IGABT
  • Reporting according to GEC ESTRO recommendations

Overall outcome published by Sturdza et al. Radioth Oncol 2016
Local control and FIGO stage (RetroEMBRACE)

Loc failure (Retro 3-5y):
- IB: 2%
- IIB: 7-9%
- IIIB: 21-25%
- IVA: 24%

Loc failure (Vienna 3y):
- IB: 0%
- IIB: 4%
- IIIB: 14%
- IVA: 2/6 (n)

*RetroEMBRACE 3y:
- IB: 98%*
- IIB: 93%
- IIIB: 79%

*2 events in IB2

RetroEMBRACE (2016) 3y:
Overall local control: 91%

Vienna (2011) 3y:
Overall local control: 95%

Sturdza et al. 2016
Pelvic control and FIGO stage

### Actuarial Probability

<table>
<thead>
<tr>
<th>PC</th>
<th>3y</th>
<th>5y</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1B</td>
<td>96%</td>
<td>96%</td>
<td>123</td>
</tr>
<tr>
<td>2B</td>
<td>89%</td>
<td>87%</td>
<td>368</td>
</tr>
<tr>
<td>3B</td>
<td>73%</td>
<td>67%</td>
<td>145</td>
</tr>
</tbody>
</table>

### Months

- RetroEMBRACE 3y: overall 87%
- Vienna (2011) 3y: overall 91%

**RetroEMBRACE Outcome Sturdza et al. 2016**
• **EMBRACE** - International study on MRI-based 3D brachytherapy in locally advanced cervical cancer

• A prospective observational multi-centre trial

• Major endpoint: local control; multiple other endpoints
  • multiple hypotheses on dose volume effects

• Enrollment of patients 7/2008-12/2015, 1416 pts accrued
EMBRACE II dose prescription

Dose de-escalation

Dose escalation: application of IC/IS

769 pts EMBRACE

HR CTV D90 85-95Gy

Tanderup 2015
2D to 3D brachytherapy for cervical cancer

A–P and L–R X-ray films → 2-D treatment planning and evaluation

- Pont A dose
- ICRU rectal and bladder reference point

MRI, CT, US → 3-D treatment planning and evaluation

- Easy for treatment planning
- No evaluate the dose of tumor and OARs

HR-CTV, IR-CTV, and OARs doses

- Evaluate the DVH analysis for HR-CTV and OARs
- Longer treatment time.
- Medical resource
Dose prescription (3D)

→ 'Individualized treatment' adapted tumor size or invasion

High-risk-CTV recommended by GEC-ESTRO

Pötter R, et al., Radiotherapy and Oncology 2006

Jichi Medical University
Representative dose distributions

DVH curves

IC  IC/IS  IS

IC/IS improves the therapeutic: Analysis from the retro EMBRACE study

<table>
<thead>
<tr>
<th>Variable doses in Gy</th>
<th>All patients (N = 610)</th>
<th>IC/IS group (N = 300)</th>
<th>IC group (N = 310)</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume HR CTV</td>
<td>36 ± 24</td>
<td>39 ± 25</td>
<td>33 ± 24</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>HR CTV D90</td>
<td>88 ± 14</td>
<td>92 ± 13</td>
<td>83 ± 14</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>D2CC Bladder</td>
<td>81 ± 22</td>
<td>79 ± 12</td>
<td>83 ± 29</td>
<td>0.07</td>
</tr>
<tr>
<td>D2CC Rectum</td>
<td>64 ± 8</td>
<td>65 ± 7</td>
<td>64 ± 10</td>
<td>0.12</td>
</tr>
<tr>
<td>ICRU Rectum</td>
<td>69 ± 13</td>
<td>69 ± 9</td>
<td>69 ± 15</td>
<td>0.84</td>
</tr>
<tr>
<td>D2CC Sigmoid</td>
<td>65 ± 10</td>
<td>65 ± 7</td>
<td>66 ± 12</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Fokdal L et al, Radiother Oncol. 2016 in press
### RT Schedules Using LDR/HDR Brachytherapy

<table>
<thead>
<tr>
<th>Weeks</th>
<th>LDR (USA)</th>
<th>HDR (Vienna)</th>
<th>HDR (Japan)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>45-50.4 Gy</td>
<td>45 Gy</td>
<td>30-(40) Gy</td>
</tr>
<tr>
<td>2</td>
<td>LDR 35-40 Gy/2 Fr</td>
<td>HDR 28 Gy/4 Fr</td>
<td>HDR 24 Gy/4 Fr</td>
</tr>
<tr>
<td>3</td>
<td>HDR 30 Gy/5 Fr</td>
<td>(BED at Point A = 84 Gy_\text{EQD2})</td>
<td>(BED at Point A = 62-(72) Gy_\text{EQD2})</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Legend:**
- **Green**: EBRT (Whole Pelvis)
- **Brown**: LDR-Brachytherapy
- **Blue**: EBRT (Central Shielding)
- **Pink**: HDR-Brachytherapy
ICRU REPORT 89
Prescribing, Recording, and Reporting Brachytherapy for Cancer of the Cervix
BRACHYTHERAPY IMAGING FOR TREATMENT PLANNING

Patient: [Incorrectly written as 'BAK 2005']

Clinical Drawing

At Diagnosis

- **Cervix**
  - Infiltrative: Red
  - Exophytic: Green

- **Vagina**
  - Red

- **Parametria**
  - Blue

- **Rectum or Bladder**
  - Orange

Vagina Involvement:
- **w = 40 cm**
- **h = 30 cm**
- **t = 50 cm**

Signature: [Incorrectly written as 'Ravon 74']

dd/mm/yy:
- 16/08/17
Panel A: Targets for EBRT

Panel B: Targets for brachytherapy
Imaging Modalities for IGBT

- MRI
- CT
- Ultrasonography
- Other possibilities
MRI

Strengths

- “Golden standard”
- Clear images of the primary tumor, parametrial tissues.
- Good evaluation of parametrial and vaginal invasion.
- Concepts of CTV (and OARs) developed on MRI findings

Limitations

- Cost (MRI itself, compatible applicators, etc)
- Time
- Area restriction/safety
- Often MRI is installed outside RT department.
CT

Strengths
- Ease of imaging (cost, time, in-room installation, etc)
- Possible application in recently developed dose-calculation algorithm.

Limitations
- Quality of the acquired image
  - Low soft-tissue differentiation
  - Possible artifact high density object/tissues, from non-compatible applicators.
## National survey of intracavitary brachytherapy for intact uterine cervical cancer in Japan

Takafumi Toita, Tatsuya Ohno, Hitoshi Ikushima, Tetsuo Nishimura, Takashi Uno, Kazuhiko Ogawa, Hiroshi Onishi, Takushi Dokiya, and Jun Itami, The Working Group of the Japanese Group of Brachytherapy/Japan Society for Radiation Oncology (JGB/JASTRO)

<table>
<thead>
<tr>
<th>Country</th>
<th>Surveillance Year</th>
<th>Number of centers</th>
<th>2D-ICBT</th>
<th>3D-ICBT</th>
</tr>
</thead>
<tbody>
<tr>
<td>US</td>
<td>2007</td>
<td>133</td>
<td>43%</td>
<td>55%</td>
</tr>
<tr>
<td></td>
<td>2014</td>
<td>219</td>
<td>15%</td>
<td>95%</td>
</tr>
<tr>
<td>Canada</td>
<td>2009</td>
<td>22</td>
<td>50%</td>
<td>45%</td>
</tr>
<tr>
<td></td>
<td>2012</td>
<td>24</td>
<td>21%</td>
<td>75%</td>
</tr>
<tr>
<td></td>
<td>2015</td>
<td>28</td>
<td>4%</td>
<td>96%</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>2015</td>
<td>16</td>
<td>0%</td>
<td>55%</td>
</tr>
<tr>
<td>Japan</td>
<td>2012</td>
<td>171</td>
<td>80%</td>
<td>14%</td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>133</td>
<td>40%</td>
<td>44%</td>
</tr>
</tbody>
</table>

CT or MRI ??

- The choice between CT and MRI is not often a question. (rather matter of resources, circumstances, etc)

- It is important to understand the characteristics of CT & MRI (tips and pitfalls) and to be aware of these characteristics when we implement treatment (planning).
• Conclusions:
  • Computed tomography-based or MRI-based scans at brachytherapy are adequate for OAR DVH analysis.
  • However, CT tumor contours can significantly overestimate the tumor width, resulting in significant differences in the D90, D100, and volume treated to the prescription dose or greater for the HR-CTV compared with that using MRI.
  • “MRI remains the standard for CTV definition.”

A smaller initial tumor with no parametrial involvement, and a small amount of residual disease to contour, with clear edges of the cervix visible on CT and MR

Fig. 3. Axial, sagittal, and coronal computed tomographic (CT) and magnetic resonance (MR) images for case 2 showing a tandem and ovoid applicator with needles with consensus contours for MR (light blue) and for CT (red).

A large tumor at diagnosis and large residual disease at the time of BT

A large tumor at diagnosis with parametrial extension that had a good response to EBRT → Large discrepancy between CT and MRI

Based on the 3 scenarios, parametrial extension may help clarify when patients may benefit from MRI at the time of BT.

- **No parametrial extension**
  - MR and CT have nearly identical CTV contours.

- **Parametrial extension and a poor response to treatment**
  - MR and CT have similar CTV contours

- **Parametrial extension with a complete response**
  - More discrepancy between CT and MRI
  - May benefit the most from the use of MRI

Conclusions: A combination of MRI for first fraction and subsequent CT based planning is feasible and easy when automatic applicator-based image registration and target transfer are technically available. The results show striking similarity to fully MRI-based planning in cases of small tumours and intracavitary applications, both in terms of HR CTV coverage and respecting of OAR dose limits. For larger tumours and complex applications, as well as situations with unfavourable OAR topography, especially for the sigmoid, MRI based adaptive BT planning remains the superior method.
1. All X-ray films

2. CT $\rightarrow$ subsequent X-ray-films

3. CT $\rightarrow$ CT $\rightarrow$ CT $\rightarrow$ CT

4. MRI+CT or MRI $\rightarrow$ CT $\rightarrow$ CT $\rightarrow$ CT $\rightarrow$ CT $\rightarrow$ CT

Japanese center

5. MRI $\rightarrow$ MRI $\rightarrow$ MRI $\rightarrow$ MRI

In-room imaging (CT) or different room imaging (CT simulation or diagnostic MRI)
Ultrasonography (US)

Strength
- Rather compact, reasonable ($)
- Good soft tissue visibility
- Application in needle insertion

Limitation
- Operator-dependent
- Depends on preparation (gas, etc)
- 2D modality
Ultrasound images used for guidance during insertion of tandem interstitial needles

(transverse plane)

Bladder
Tumor
- Tandem
- Needle

(sagittal plane)

Uterine body
Bladder
Tumor
- Tandem
- Needle
Limitation of MRI-based high risk CTV contouring

For the GTV, the most frequent cause of inter-observer variability was associated with variability in the manual adjustments of the window levels and window widths of the MR images. This effect was particularly pronounced in the caudal portions of the GTV. Clinical examination!

(Dimopoulos JCA, Radiother Oncol. 2009)

Imaging quality is the decisive factor.
Summary

- MRI is considered to be the “golden standard”.
  - Target concept (delineation) established, clinical data available.

- Identification of $HR-CTV_{(CT)}$ may overestimate the width.
  - PM involvement + good response to EBRT

- The discrepancy between contouring of HR-CTV by CT and MRI may be reduced by:
  - information of clinical gynecological examination
  - diagnostic MRI (at Diagnosis, at pre-BT)
  - understanding of guidelines

- Information from ultrasonography may be useful in interstitial needle insertion and brachytherapy planning.
MRI: “Golden Standard”

↑

CT: Practice
MRI: Reference (Ideal)

- Clinical Gynecological Examination
- Diagnostic MRI (at Diagnosis)
- Diagnostic MRI (pre-BT)
- Understanding Guidelines

CT: “Standard” in Actual Practice
**Definition of high risk CTV**

The CTVs are defined according to the imaging modality used when contouring for brachytherapy treatment planning. For all CTV contouring modalities, clinical examination findings at the time of brachytherapy were also used.

1. **MRI-based high risk CTV (CTV_{HR})**
   MRI with applicator insertion
   → GEC-ESTRO recommendations

2. **CT-based high risk CTV (CTV_{HR})**
   CT with applicator insertion and MRI just before first brachytherapy
   → JASTRO/JROSG recommendation
   (Ohno T. et al. JRR 2016)

3. **CT-based CTV:**
   CT with applicator insertion
   MRI is not mandatory
   → NRG guideline
   (Viswanathan A. et al IJROBP 2014)
Comparison and Consensus Guidelines for Delineation of Clinical Target Volume for CT- and MR-Based Brachytherapy in Locally Advanced Cervical Cancer

Akila N. Viswanathan, MD, MPH, * Beth Erickson, MD, †
David K. Gaffney, MD, PhD, ‡ Sushil Beriwal, MD, ‡
Sudershan K. Bhatia, MD, PhD, ¶ Omer Lee Burnett III, MD, ¶
David P. D’Souza, MD, ** Nikhilesh Patil, MD, **
Michael G. Haddock, MD, †† Anuja Jhingran, MD, ††
Ellen L. Jones, MD, PhD, §§ Charles A. Kunos, MD, PhD, §§
Larissa J. Lee, MD, * Lilie L. Lin, MD, ††† Nina A. Mayr, MD, PhD, †††
Ivy Petersen, MD, †† Primož Petric, MD, †††† Lorraine Portelance, MD, ††††
William Small Jr, MD, §§§ Jonathan B. Strauss, MD, §§§
Kanokpis Townamchait, MD, * Aaron H. Wolfson, MD, §§§
Catheryn M. Yashar, MD, ††† and Walter Bosch, DSc §

CT-CTV contouring (updated in 2014)

MRI is not mandatory

1. Inferiorly at the level of the ring, contour tissue inside the central ring. For ovoids, contour tissue to the level of the ovoids. Add vaginal tissue adjacent to the ring if involved at the time of BT.

2. Superiorly, contour to the level where the uterus indents (internal os); draw the next 1 cm as a pointed shape (cone). The approximate dimension (height) of cervix should be 3 cm.

3. Laterally, parametrial extension should be included in the CT-CTV (and not a separate structure) if it appears “grey/white” on the CT (i.e., a similar density to the cervix). There is no need to draw the parametrial region if it does not have stranding visible on the CT or if it is not noted in the clinical drawing. IV contrast medium is not mandated. Do not include bowel directly adjacent to the cervix that may be difficult to distinguish.

4. Take into account tumor present on clinical examination and MRI findings at time of BT if available. Disease extension on clinical exam and MRI at the time of diagnosis should be contoured in a low-dose region (intermediate risk [IR]-CTV).

5. Pathologic residual tissue(s) identified in the uterus, vagina, rectum, and/or bladder are included in the CT-CTV.

Limitation of CT-based CTV contouring

**Superior border** is unclear when tumor invaded uterine corpus at the time of brachytherapy.

(Viswanathan A. et al IJROBP 2014)
## Planning aims and limits for target in EMBRACE-II

<table>
<thead>
<tr>
<th></th>
<th>D90 CTV&lt;sub&gt;HR&lt;/sub&gt; EQD2 10</th>
<th>D98 CTV&lt;sub&gt;HR&lt;/sub&gt; EQD2 10</th>
<th>D98 GTV&lt;sub&gt;res&lt;/sub&gt; EQD2 10</th>
<th>D98 CTV&lt;sub&gt;IR&lt;/sub&gt; EQD2 10</th>
<th>Point A EQD2 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning aims (soft constrain)</td>
<td>&gt;90 Gy &lt;95 Gy</td>
<td>&gt;75 Gy</td>
<td>&gt;95 Gy</td>
<td>&gt;60 Gy</td>
<td>&gt;65 Gy</td>
</tr>
<tr>
<td>Limits for prescribed dose (hard constrain)</td>
<td>&gt;85 Gy</td>
<td>-</td>
<td>&gt;90 Gy</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

OARs

• Tissue organization also within certain organs that are a mixture of parallel and serial organization (Dörr and Van der Kogel, 2009)

• Rectum:
  • Serial – transportation
  • Parallel (vessel, wall) – Rectal bleeding or ulceration or fistula
Filling status

- Bladder filling: two concepts 1. treat as empty bladder (Mazeraon et al 2014) 2. treat as limited filling status (50cc) after emptying of the bladder (provides a specific distance between anterior and posterior bladder wall but not lead to major filling of the lateral bladder recesses (Potter et al 2011)
- Recto sigmoid and other bowel, empty rectosigmoid is usually incorporated by enema; gas and feces accumulation has to be avoided as much as possible (to avoid the variations in luminal volume and in wall location)
- Vaginal applicator+the packing = should visualize in the imaging and show adequate distension of the vaginal wall throughout the imaging procedure and the subsequent irradiation

ICRU-89, 2013
OARs

- Brachytherapy-related morbidity is usually linked to small volumes receiving high absorbed doses
- 0.1 cm³ and 2 cm³ is recommended in report
## Planning aims and limits for OAR in EMBRACE-II

<table>
<thead>
<tr>
<th></th>
<th>Bladder D2cm³ EQD2 3</th>
<th>Rectum D2cm³ EQD2 3</th>
<th>Recto-vaginal point EQD2 3</th>
<th>Sigmoid D2cm³ EQD2 3</th>
<th>Bowel D2cm³ EQD2 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Planning aims</strong></td>
<td>&lt;80 Gy</td>
<td>&lt;65 Gy</td>
<td>&lt;65 Gy</td>
<td>&lt;70 Gy</td>
<td>&lt;70 Gy</td>
</tr>
<tr>
<td>(soft constrain)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Limits for prescribed dose</strong></td>
<td>&lt;90 Gy</td>
<td>&lt;75 Gy</td>
<td>&lt;75 Gy</td>
<td>&lt;75 Gy</td>
<td>&lt;75 Gy</td>
</tr>
<tr>
<td>(hard constrain)</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Level 1: Minimum standard for reporting</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Volumetric imaging approximation based on:</strong></td>
</tr>
<tr>
<td>Baseline morbidity and QoL assessment according to international classification systems</td>
</tr>
<tr>
<td>Reference volumes on 3D images:</td>
</tr>
<tr>
<td>Assessment of small organ volumes (0.1 cm³ and 2 cm³) for brachytherapy-related morbidity through outer-wall contouring on volumetric images in the treatment planning system:</td>
</tr>
<tr>
<td>(1) bladder contour/volume;</td>
</tr>
<tr>
<td>(2) Rectum contour/volume.</td>
</tr>
<tr>
<td>Recto-vaginal reference point (positioned on volumetric images)</td>
</tr>
<tr>
<td><strong>Radiographic approximation based on:</strong></td>
</tr>
<tr>
<td>Baseline morbidity and QoL assessment according to international classification systems</td>
</tr>
<tr>
<td>Reference point location on radiographs or on a treatment plan:</td>
</tr>
<tr>
<td>(1) Bladder reference point</td>
</tr>
<tr>
<td>(2) Recto-vaginal reference point</td>
</tr>
</tbody>
</table>
Level 2: *Advanced standard for reporting*
All that is reported in level 1 plus:

<table>
<thead>
<tr>
<th>Volumetric-imaging approximation based on:</th>
<th>Radiographic approximation based on:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bladder reference point (positioned on volumetric images)</td>
<td>Vagina reference points (on radiographs):</td>
</tr>
<tr>
<td>Assessment of small organ volumes (0.1 cm³ and 2 cm³) for brachytherapy-related morbidity through outer-wall contouring on volumetric images in the treatment-planning system:</td>
<td>Upper-vagina points (5 mm lateral from vaginal applicator surface, right and left) for brachytherapy-related morbidity</td>
</tr>
<tr>
<td>(1) Sigmoid-colon contour/volume;</td>
<td>Anatomical points for lower and mid vagina (PIBS, PIBS ± 2 cm), for morbidity from EBRT and brachytherapy (on radiographs)</td>
</tr>
</tbody>
</table>
Level 2: Advanced standard for reporting
All that is reported in level 1 plus:

(2) Bowel contour/volume (adjacent, fixed)
Assessment of intermediate- and large-organ volumes for EBRT- and brachytherapy-related morbidity through outer-wall contouring on volumetric images in the treatment-planning system:

(1) Bladder contour/volume
(2) Rectum contour/volume
(3) Sigmoid-colon contour/volume
(4) Bowel (adjacent) contour/volume

Vagina reference points (all contoured on volumetric images):

(1) Upper-vagina points (5 mm lateral from vaginal applicator surface, right and left) for brachytherapy-related morbidity;
Level 3: *Research-oriented reporting*
All that is reported in Level 1 and 2 plus:

<table>
<thead>
<tr>
<th>Volumetric-imaging approximation based on:</th>
<th>Radiographic approximation based on:</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Volumes or surface for vagina;</td>
<td>(1) Other bladder points;</td>
</tr>
<tr>
<td>(2) Vaginal reference length/volume</td>
<td>(2) Anatomical anal reference point;</td>
</tr>
<tr>
<td>(3) Bladder sub-volumes, for example, the neck or wall;</td>
<td>(3) Sigmoid-colon and small/large bowel reference points;</td>
</tr>
<tr>
<td>(4) Small volumes for anus; anal reference point;</td>
<td>(4) Vaginal reference length</td>
</tr>
<tr>
<td>(5) Remaining volume of interest: body outline;</td>
<td></td>
</tr>
<tr>
<td>(6) Other sub-volumes of potential interest</td>
<td></td>
</tr>
</tbody>
</table>
Dose Reporting

- High dose gradient: D98 %, D90 %, D50 % are used to report in brachytherapy
Level 1: Minimum standard for reporting

Dose reporting
- TRAK
- Point A dose
- Recto-vaginal reference point dose
- $D_{0.1\text{cm}^3}, D_{2\text{cm}^3}$ for the bladder, rectum
Level 2: Advanced standard for reporting
All that is reported in level 1 plus

Dose reporting for defined volumes
• $D_{98\%}, D_{90\%}, D_{50\%}$ for the $CTV_{HR}$
• $(D_{98\%}, D_{90\%}$ for the $CTV_{IR}$ if used for prescription)
• $D_{98\%}$ for $GTV_{res}$
• $D_{98\%}$ for pathological lymph nodes

Dose reporting OARs
• Bladder reference-point dose
• $D_{0.1\text{cm}^3}, D_{2\text{cm}^3}$ for the sigmoid
• $D_{\text{cm}^3}$ for the bowel
• Intermediate- and low-dose parameters for the bladder, rectum, sigmoid, and bowel (e.g., $V_{15\text{ Gy}}, V_{25\text{ Gy}}, V_{35\text{ Gy}}, V_{45\text{ Gy}},$ or $D_{98\%}, D_{50\%}, D_{2\%}$)
• Vaginal point doses at level of sources (lateral at 5 mm)$^a$
• Lower and mid-vagina doses (PIBS, PIBS $\pm 2$ cm)$^a$
Level 3: *Research-oriented reporting*
All that is reported in Level 1 and 2 plus

Absorbed-dose reporting for the tumor:
- $D_{98\%}$, $D_{90\%}$ for the CTV_{IR} even if not used for prescription
- $D_{90\%}$ for the GTV_{res}
- DVH parameters for the PTV
- $D_{50\%}$ for pathological lymph nodes
- DVH parameters for non-involved nodes (ext/int iliac, common iliac)

OAR volumes and points
- Additional bladder and rectum reference points
- OAR sub-volumes (*e.g.*, trigonum or bladder neck, sphincter muscles)
- Vagina (upper, middle, lower)
- Anal canal (sphincter)
- Vulva (labia, clitoris)
- Other volumes/sub-volumes of interest (*e.g.*, ureter)

Dose–volume reporting for OARs
- Dose–volume and DSH parameters for additional OARs and sub-volumes
- Vaginal dose profiles, dose–volume, and DSHs
- Length of treated vagina

Isodose surface volumes
- 85 Gy EQD2 volume
- 60 Gy EQD2 volume
BT PROCEDURE

STANDARD INTACAVITARY (IC)

ADVANCED IC + IS

INERTSTITIAL TEMPLATE BASED BT PROCEDURES

HURDLES

- AVAILABILITY

- EXPERTISE AND SKILLS

- TRAINING : HANDS-ON

- AUDIT
GYN BT APPLICATOR
AVAILABILITY

STANDARD INTACAVITARY (IC)

ADVANCED IC + IS

INERTSTITIAL TEMPLATES

HURDLES

-AVAILABILITY

- EXPERTISE AND SKILLS

- TRAINING
IMAGING DURING BT

ORTHOGONAL RADIOGRAPHY

GOLD STANDARD: MR IMAGING

CT +/- TRANS-RECTAL ULTRASONOGRAPHY

HURDLES

- AVAILABILITY

- EXPERTISE AND SKILLS

- TRAINING
TREATMENT PLANNING

APPLICATOR RECONSTRUCTION

BASIC & ADVANCED TREATMENT PLANNING

PLAN EVALUATION & REPORTING

HURDLES

- EXPERTISE AND SKILLS

- TRAINING

- AUDITS